WISPAS

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Root growth of young Veronese poplars on erodible slopes in the southern North Island, New Zealand.

In New Zealand poplars are commonly planted on moist, unstable hill country to prevent or reduce soil erosion. Planting patterns and materials vary from high density plantings (up to 1500 trees ha^{-1}) of unrooted 1 m stakes on more actively eroding and unstable sites retired from grazing, to widely-spaced (25-150 trees ha^{-1}) hillslope planting of 3 m poles on partly unstable grazed hill country. Slips often occur just below gently sloping hillcrests where downhill slopes become steeper, frequently because of seepage water from the flats flowing over impervious layers. One or two rows of poplars or tree willows spaced 8-12 m apart are planted in this change of slope area.

The distribution and morphology of the poplar root system have a key influence on soil physical properties, such as soil strength and soil water content, which in turn influence both soil stability and pasture growth. Root-reinforced soil is more able to resist continued deformation, without loss of residual strength, than soil alone. Direct-shear tests of soil-root composites have demonstrated that soil shear strength increases linearly with increasing root mass. However, there are no published studies that investigate the root direction, distribution and size of poplar roots in hill country plantings.

Figure 1. In the trenches - downslope excavated roots of the 9.5 yr 'Veronese' poplar showing the different root diameters and variable extension paths from the stump.

We excavated the structural roots for three *Populus deltoides* × *nigra* 'Veronese' trees aged 5, 7 and 9.5 yr planted as 3 m poles at 8 m x 8 m spacing on a 17° hillslope near Palmerston North in the southern North Island, and determined their root mass, root length and distribution. The soil was a Kumeroa hill soil, primarily fine sandy loam with a clay content of 18 to 20%, low organic matter content, and low macroporosity formed on a shallow fragipan of Tertiary sedimentary stone.

Dimensions of the excavated trees

The heights and DBHs of the excavated trees are shown in Table 1. All of the excavated trees had heights and DBHs that were close to the plantation averages for their age (data not shown). At 13.3 m the 9.5 yr tree was nearly twice the height of the 5 yr tree, which was 7.3 m tall. Trunk cross-sectional area in the 9.5 yr tree was 356 cm^2, over six times greater than that in the 5 yr tree at 55 cm^2. Root growth was relatively low in the first five years as shown by root mass: trunk cross-sectional area yet there was considerable root extension in that time.

Table 1. Dimensions of excavated 'Veronese' poplars together with relationships between trunk dimensions and mass (excluding root crown) and length of structural roots (>2 mm diameter), for trees of three ages.

Tree age (yr)	Height (m)	DBH (cm)	Trunk cross-sectional area (cm^2)	Root length (m)	Root mass (kg DM)	Root mass: trunk area	Root length: trunk area
5	7.3	8.4	55.4	79.4	0.57	0.010	1.43
7	9.0	14.0	153.9	349.3	7.80	0.051	2.26
9.5	13.3	21.3	356.1	663.5	17.90	0.050	1.87

Radial root distribution

Radial distribution of structural roots was variable around the trees at each age, and differed between upslope and downslope sides of the trees (Figure 2). Roots changed direction and depth frequently and they regularly crossed each other. Roots in the downhill direction were closer to the surface than those roots following an uphill path.

For all of the excavated trees radial roots were generally found within 40 cm of the ground surface, with many being located within 15 cm of the surface. Only those radial roots growing uphill penetrated deeper and then only for distances <2 m.

The upslope pattern of root growth extended the root network through a greater depth of soil further away from the trunk than did the downslope growth pattern. At all tree ages, root growth upslope followed a stepwise pattern. Roots growing upslope typically grew horizontally and so deeper in to the slope to depths of up to 90 cm. At some point in time the direction of growth abruptly turned almost vertically upwards until the root again approached a depth of around 10 cm, and then proceeded in a horizontal or downhill direction once again. Radial roots growing downslope rarely grew below 10 cm of the soil surface, except at their terminus.

Sinker root distribution

Sinker roots with proximal diameters <5 mm occurred at irregular intervals along the length of the radial roots and extended to depths of 40-70 mm before branching into roots <2 mm diameter. None reached the fragipan depth of 1 m. For

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the tree aged 9.5 yr, there were 39 sinker roots with a mean length of 34 (range 20-60) cm and penetrating to a mean depth of 48 (20-90) cm below the surface, with a root mass of 0.13 kg. This represented 0.8% of radial root mass for the 9.5 yr tree.

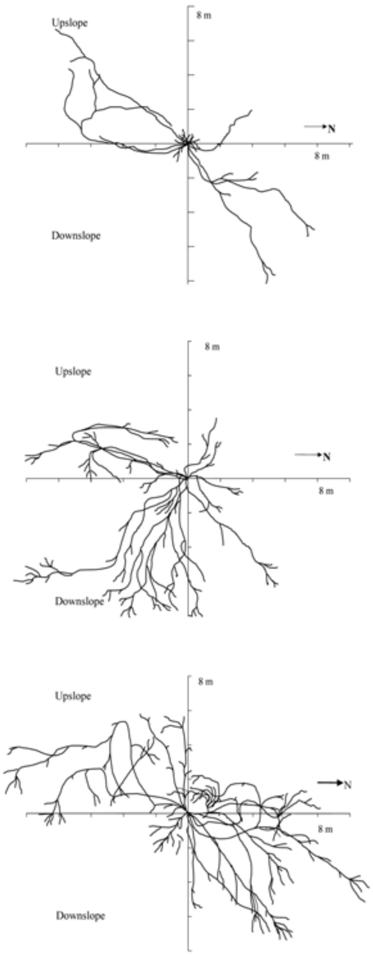

Figure 2. Radial distribution of structural roots (>2 mm diameter) of 'Veronese' poplar trees aged 5 yr (top), 7 yr (middle) and 9.5 yr (bottom) growing on hill country near Palmerston North, New Zealand.

Vertical root distribution

Vertical roots close to the root crown extended downwards either directly from the root crown or from a large radial root at distances up to 20 cm from the root crown. They penetrated the soil to a maximum depth of about 1.0 m, where the fragipan restricted root penetration. The vertical roots grew horizontally across the surface of the fragipan for 40-60 cm. The vertical roots had proximal diameters >10 mm.

Vertical root mass was 15% of total root mass (17.9 kg DM) for the 9.5 yr tree and 12% for the 7 yr tree (7.8 kg DM). The root bole is excluded from these data.

Root mass density and length density distribution

Root mass density distribution measured from the trunk was similar for all three trees, being highest within 0-2 m from the trunk and lowest within 8-10 m from the trunk (Figure 3a).

Continued on page 3

The Project Manager

This **WISPAS** we honour as our Professional - The Project Manager.

Management Myths

The first myth of management is that it exists. The second myth of management is that success equals skill.

Robert Heller, *US editor*

Augustine's Law

If a sufficient number of management layers are superimposed on top of each other, it can be assured that disaster is not left to chance.

Norman Augustine,
US business executive

Boulding's Hierarchy

A hierarchy is an ordered arrangement of wastebaskets designed to prevent information reaching the executive.

Kenneth Boulding, *Economist*

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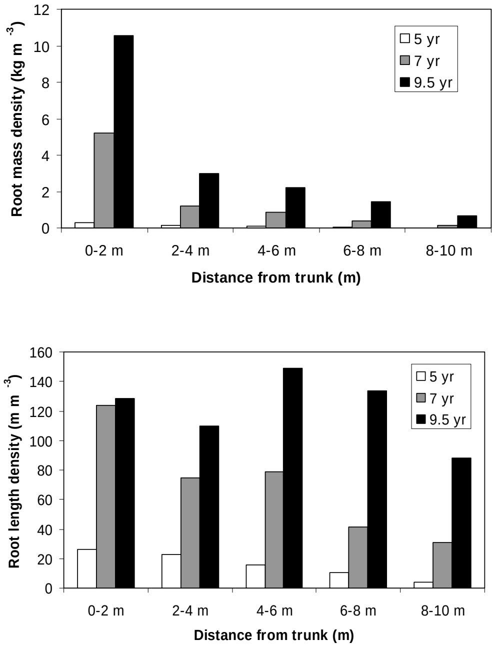


(a)

(b)

Figure 3. *Total root mass density (a) and total root length density (b) at different distances from the trunk of 'Veronese' poplar trees aged 5 yr, 7 yr and 9.5 yr growing at 8 m x 8 m spacing on hill country near Palmerston North, New Zealand.*

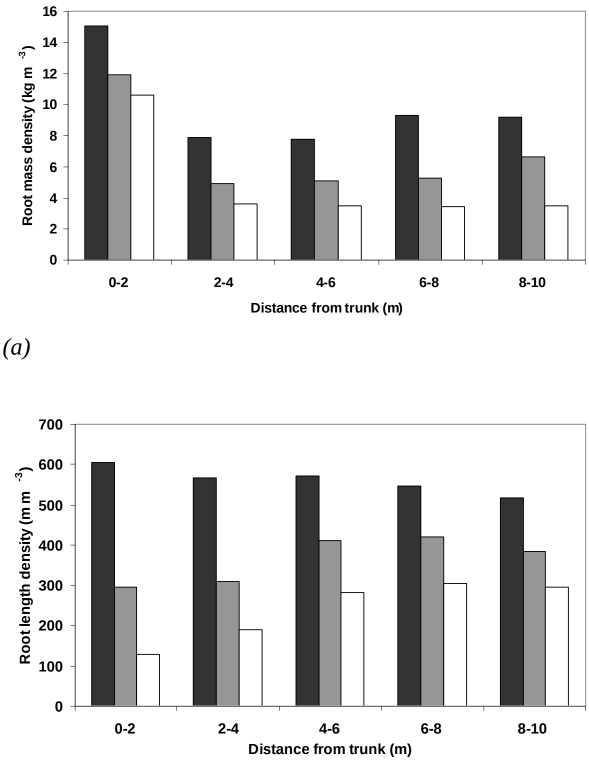
The proportion of total root length for structural roots with diameter >20 mm was similar for the yr 7 tree (5.9%) and the year 9.5 tree (6.0%), and for roots with diameter 2-5 mm was 54.9%, 47.8% and 53.1% respectively for the 5 yr, 7 yr and 9.5 yr trees. Root length density around trees aged 5 yr and 7 yr generally declined as distance from the trunk increased (Figure 2b). This contrasted with the 9.5 yr tree where root length density was similar at each 2 m interval outward from the trunk to 8 m. At 8-10 m from the trunk, root length density of the 9.5 yr tree was 35% less than at 0-2 m, compared with 76-80% less for the two younger trees.

Simulated root mass and root length density in a wide-spaced plantation

Densities of the total structural root mass and root length around the 9.5 yr excavated tree, contributed by roots from both the excavated tree and the surrounding trees, were calculated using a short, purpose-written programme (A Hall, pers. comm. 2005). This was conducted for an 8 m x 8 m spacing (156 stems ha^{-1}), as occurred in this study, and spacings of 10 m x 10 m (100 stems ha^{-1}) and 15 m x 15 m (44 stems ha^{-1}). At all distances from trees, estimated densities of root mass and root length were highest for trees at 8 m x 8 m spacing, intermediate at 10 m x 10 m spacing, and lowest for trees at 15 m x 15 m spacing (Figures 4a, b). Root mass density at all spacings was highest within 0-2 m of the trunk, and 50-80% less at all greater distances from the trunk (Figure 4a). Root length density was approximately constant across the five distance ranges from the trunk for the 9.5 yr tree, whereas for both younger trees, it increased slightly as distance from the trunk increased (Figures 4b, 3b).

At the 8 m x 8 m spacing in this study, the contribution of all trees increased mean root mass density three times and mean root length density 4-5 times that contributed by the single tree at 9.5 yr.

The study indicated that root development of wide-spaced poplar trees on hillslopes was minimal in the first five years but then increased rapidly. It is concluded that the minimum structural root network required for poplar trees to effectively bind soil does not develop until at least five years.



(a)

(b)

Figure 4. *Estimated root mass density (a) and root length density (b) at different distances from the trunk of a 'Veronese' poplar tree aged 9.5 yr grown at different spacings including the contribution of all adjacent trees. Bars at each distance are for tree spacings of 8 m x 8 m (highest), 10 m x 10 m (intermediate) and 15 m x 15 m (lowest).*

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Nitrate leaching from gorse – A study from New Zealand

Nitrogen (N) is often the most growth-limiting nutrient in both terrestrial and aquatic systems. Widespread concern about increasing concentrations of nitrate in surface and ground water has focused attention on nitrate leaching in recent years. Identification of the source and extent of nitrate leaching losses on a catchment scale has been difficult. Many studies in the past have examined the contribution of N from various sources such as agricultural lands, fertilizers, grazing animals, and land application of wastes. However, no detailed work has been carried out on the contribution to surface water quality in terms of N loading of invasive, leguminous weeds such as gorse and broom, although such weeds have invaded large areas of New Zealand's agricultural and forested lands.

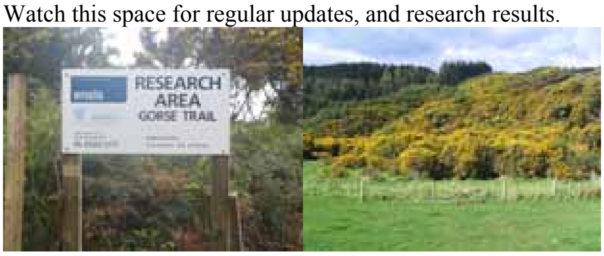
Egunjobi (1969) studied nine ecosystems in New Zealand, involving gorse (*Ulex europaeus* L.) and associated shrubs and trees. He found gorse was superior to other species in its ability to accumulate dry matter, litter and nitrogen content. The dry matter accumulation of gorse stands was at an average annual rate of between 10,000-15,000 kg ha^{-1} yr^{-1} when the stands were young (less than 10 years old). It decreased with age (c. 3,000-4,000 kg ha^{-1} yr^{-1} for stands between 16 and 33 years old).

Egunjobi (1969) also reported that the N concentration was high in the soils under gorse stands because of its nitrogen-fixing ability and the large quantities of litter it produced. The gorse-dominated stands accumulated more nitrogen per unit area than older stands dominated by non-nitrogen-fixing shrubs and trees. During the period of rapid dry-matter accumulation, nitrogen accumulated at a rate of 100 to 200 kg ha^{-1} yr^{-1} in gorse stands.

In another study, Dyck et al. (1983) studied nitrate losses from different disturbed ecosystems. They found that under controlled conditions more nitrate was leached from sites under gorse, than from sites under other species. For example, nitrate-N concentrations from the gorse area averaged 5 g m^{-3} whereas nitrate from Radiata pine averaged 0.006 g m^{-3} (Table 1). In the same study, Dyck et al (1983) suggested that decomposing gorse tissue released fairly large amounts of N which are nitrified and enter the groundwater.

The overall aim of this research programme is to assess the contribution of nitrate leaching to ground water from release of accumulated N in litter and soils of stands of gorse for a range of soil types. We run laboratory experiments in parallel with field experiments. This is to understand both the processes of N release and leaching under controlled conditions and compare to a range of field situations.

Watch this space for regular updates, and research results.



References

Dyck WJ, Gosz JR, and Hodgkiss PD. 1983. Nitrate losses from disturbed ecosystems in New Zealand - A comparative analysis. *New Zealand Journal of Forestry Science*, 13(1): 14-24.

Egunjobi JK. 1969. Dry matter and nitrogen accumulation in secondary successions involving gorse (*Ulex Europaeus* L.) and associated shrubs and trees. *New Zealand Journal of Science*, 12: 175-193.

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Table 1. Average nitrate-N concentrations leaching from control sites under various plant species (adapted from Dyck et al. 1983).

Plant species	Age (years)	Stocking rate (stems ha^{-1})	Soil type	Monitoring Period (year)	Average nitrate-N conc. (g m^{-3})	Leaching* (kg^{-1} ha^{-1} yr^{-1})
Radiata Pine	20	250	Kaingaroa silty sand	2	0.006	0.04
Douglas fir	56	200	Te Rere sand	2	0.272	1.9
E. Saligna	18	100	Manawahe coarse sand	1	0.08	0.56
Gorse	20	Dense	Galatea sand	2	5.1	35.7

*assuming 700 mm drainage per year.

Environmental Cycle

The environmental debate is conducted in a predictable cycle: Science discovers another negative human impact on the environment. Trade groups and businesses counter, the media reports both sides, and the issue eventually gets consigned to a growing list of unresolved problems. The point is not that one side is right and the other wrong but that the episodic nature of news, and the compartmentalization of each successive issue, inhibit devising solutions. Environmentalists appear like Cassandra, business looks like Pandora, apologists sound like Dr Pangloss, and the public feels paralyzed.

Paul Hawken, Amory Lovins and L. Hunter Lovins. 1999
Natural Capitalism: Creating the Next Industrial Revolution
Little, Brown & Co. NY

Souk Science 101

The soil is less a factory than a souk, a Casbah, a flea market, an economic free-for-all in which each buyer and seller pursues his or her own interest, and in which every scrap of mechandise – second-hand, seventh-hand, busted, salvaged, patched – is mined for its last ounce of value. Decay is good business because there are nutrients to be extracted and energy to be gained from the breaking of chemical bonds. If the net effect of the activity of the soil biota is overwhelmingly helpful – in fact, vital – to life on street level, it is not because nature has ordained it so, but because the various forms of life above and below ground have coevolved.

E Eisenberg. 1998
The Ecology of Eden
Published by Alfred A. Knopf, NY

Effect of available nitrogen on the N2-fixation by gorse (*Ulex europaeus* L.) and broom (*Cytisus scoparius* L.)

Woody leguminous plants (*Fabaceae*) such as gorse (*Ulex europaeus* L.) and broom (*Cytisus scoparius* L.) are common weed species that can fix N_2 from the atmosphere. Potentially these species may result in accumulation of biologically available N in soil. The N may be leached to groundwater and eventually contribute to eutrophication of surface water bodies. There is evidence that applying N fertiliser normally suppresses clover's ability to fix N_2 in pasture, but there is little information on the effect of existing soil available N on the symbiotic N_2 fixation in woody leguminous plants such as *U. europaeus* and *C. scoparius*.

Acetylene Reduction Assay (ARA) was used to assess the relationship between available N concentration in the growth media and fixation of N_2 by *U. europaeus* and *C. scoparius* plants. The study is based on a glasshouse experiment where plants were grown in pots filled with washed coarse gravel. Manuka and blackberry (*Leptospermum scoparium* L. and *Rubus fructicosus* L.) were chosen as non-N_2 fixing reference plants. In addition, a control treatment (no plants in pot) was also included. Modified Hoagland nutrient solution containing normal concentrations of nutrients except N were added to the pots weekly. There were seven N treatments, including 0, 50, 100, 200, 400, 800, 1600 mg N/L as ammonium sulphate, that are equivalent to 2.9, 5.7, 11.4, 22.8, 45.7 and 91.4 mM N, respectively. Each treatment had three replications with a total of 105 pots being laid out in a randomised complete block design.

Preliminary results showed that N_2 fixation in *U. europaeus* and *C. scoparius* decreased with increase of available N in nutrient solution. Gorses seemed to fix more than brooms. Evolution of ethylene appearance was found to be linear with time after injection of acetylene. More N_2 was fixed in *U. europaeus* and *C. scoparius* plants grown in no N and low N treatments. Little N_2 fixation activities when the available N concentration in nutrient solution was 400 mg or higher (Figure 1). However, large variations in the results made it difficult to decide a threshold for N_2 fixation in either *C. scoparius* or *U. europaeus*.

Further study in glasshouse and field trials will be conducted using ^{15}N dilution technique to quantify the effect of available nitrogen on the N_2-fixation.

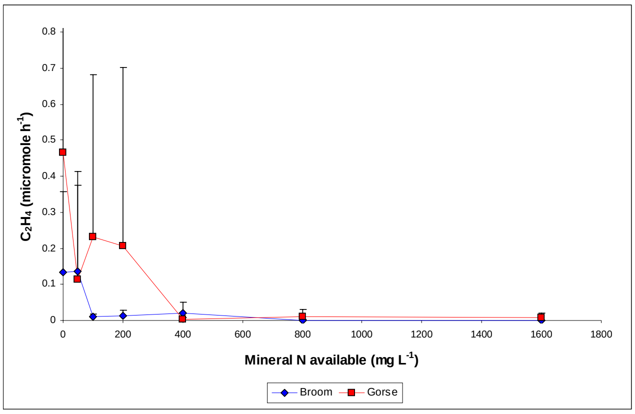

Figure 1. Evolution of ethylene appearance as a function of the available N in the nutrient solution.

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Scrutinising Science

Until the 1960s at least, the scientific knowledge production process of the Government Research Establishments (GREs) closely emulated the Mertonian ideas of what Ziman (2000) has called 'academic' science. In the 1960s and, increasingly in the 1970s, some efforts were made to shift the GREs to the production of more 'useful' science. This attempted transformation was organic and gently exhortational in approach and largely failed.

This legitimacy given to the vision of 'useful' science did however pave the way for the New Public Management (NPM) reforms of successive Conservative governments from 1979, and Labour governments since, to complete the transformation of the knowledge production process to a commodified form.

According to Ziman

The transition from academic to post-academic science [commodified] is signalled by the appearance of words such as management, contract, regulation, accountability, training, employment, etc. which previously had no place in scientific life. This vocabulary did not originate inside science, but was imported from the more 'modern' culture which emerged over several centuries in Western societies – a culture characterised by Weber as essentially 'bureaucratic'.

He characterises these as:

Propriety (knowledge that is not necessarily made public);
Local (focused on local technical problems rather than on general understanding);
Authoritarian (researchers acting under managerial authority rather than as individuals);
Commissioned (to achieve practical goals rather than in the pursuit of knowledge), and;
Expert (researchers employed as expert problem solvers rather than for personal creativity). (Ziman, 2000).

[Reference: Ziman J. 2000. Real Science: What it is and What it Means. Cambridge University Press.]

There may be little rationality or intentionality in the current design and operation of science and technology service providers to government, despite the supposed rational and intentional approach of NPM. The reasons for this paradox lies in the particular nature of the science and technology work that the GREs did, and which government still needs, which frustrated the NPM enterprise. Finally the very heterogeneity now present in the system will, inevitably, make effective management of this area of work highly problematical.

Excerpts from:
R. Boden, D. Cox, M. Nedeva and K. Barker. 2004
Scrutinising Science: The Changing UK Government of Science
Palgrave MacMillan, 209 pp. ISBN 0-333-74969-3

The effectiveness of pasture irrigation in the autumn shoulder of the irrigation season

Preamble

This article summarises the 2006 MSc project of Wageningen student Ms Kelly Leers, completed at Lincoln University. Results we report include (inter alia) determination of a critical soil moisture deficit, and water and solar energy use efficiency values for irrigated pasture.

Introduction

Canterbury is New Zealand's thirsty province! While it occupies only 17% of New Zealand land area, it has 70% of New Zealand's irrigated land, and uses 58% of New Zealand's consumptive water use. Dairy farming continues its expansion, with water use reaching or over-stepping limits of sustainable use in some locations and seasons. There is an observed tendency among some growers to "place a safe bet" by continuing to irrigate or over-irrigate towards the end of the growing season.

This project examined the effectiveness of end-of-season irrigation of pasture, in order to determine the minimum soil water required to maintain full pasture growth, and thus contribute to water conservation.

The experiments

The field experiment was carried out at the lysimeter site of Lincoln University's Centre for Soil & Environmental Quality (Figure 1), to determine the effectiveness of sprinkler irrigation applications on pasture production.

Figure 1. Irrigation being applied to eight of the 16 lysimeters.

The experiment ran for eight weeks between March and May 2006. Of the 16 large monolith lysimeters, eight were irrigated (I) while the remaining eight were not (non-I). All contained perennial ryegrass (*Lolium perenne)* and white clover (*Trifolium repens)* pasture on a Templeton fine sandy loam (Udic Ustochrept). Soil water content was monitored in two of the lysimeters, via Campbell Scientific CS 615 TDR probes at five depth intervals.

After an initial grass cut on 24 March, pasture on all 16 lysimeters was cut weekly for eight weeks up to 18 May. An initial irrigation of 75 mm was applied to fill the eight 'I' lysimeters to field capacity (FC was obtained from historic TDR probe readings over the 2005 winter period). Then a regular irrigation routine was developed. See Figure 2. The non-I lysimeters depended on rainfall for soil moisture recharge. For the I lysimeters (which also received rainfall), the initial irrigation requirement was estimated to be 75 mm, based on the TDR data for the two instrumented lysimeters. During the first two-week period irrigation requirements were calculated using a simple water budget, resulting in applications of 30 and 15 mm at the ends of weeks 1 and 2. From week 3 on, the I lysimeters received 5 mm every second day. This schedule was based on a survey of the practices of irrigating dairy farmers in the autumn-shoulder season. On two days (25 and 26 April) all lysimeters were covered to prevent waterlogging, due to heavy rainfall.

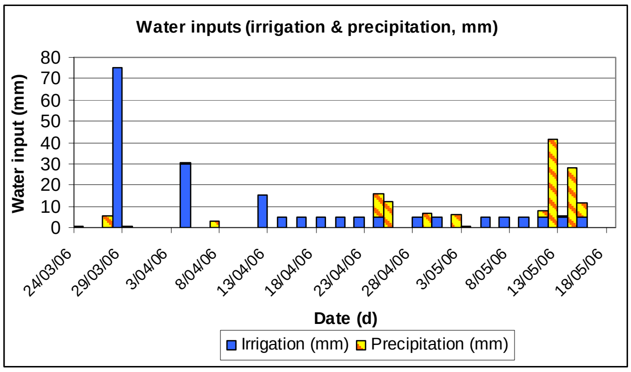

Figure 2. Water inputs from irrigation and rain. I lysimeters received both, while non-I lysimeters received only rainfall.

The results

Figure 3 illustrates the influence of irrigation on pasture dry matter (DM) production. At the end of week 1, I and non-I yields were very similar, but the following month production was obviously higher for I than for non-I lysimeters. The last three points (for May), show the I and non-I lysimeters reaching comparable yields again.

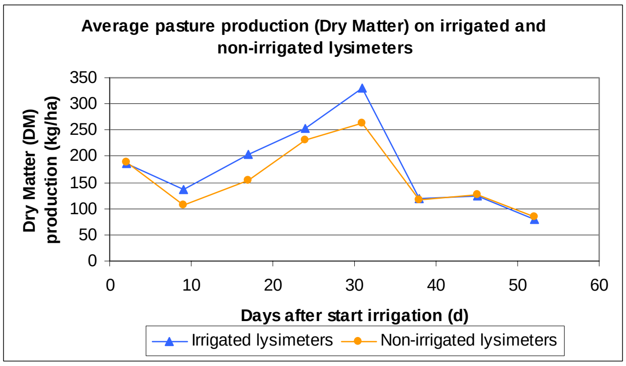

Figure 3. Pasture production related to irrigation treatment (irrigated v. non-irrigated).

Critical deficit (CD)

In order to find the Critical Deficit (CD), i.e. the point where the soil moisture deficit (SMD) starts to reduce yield, the ratio of non-I yield divided by I yield was plotted against SMD in Figure 4. Yield reduction is experienced beyond 66 mm SMD, so CD ≈ 66 mm for pasture on Templeton soils under the conditions of this experiment.

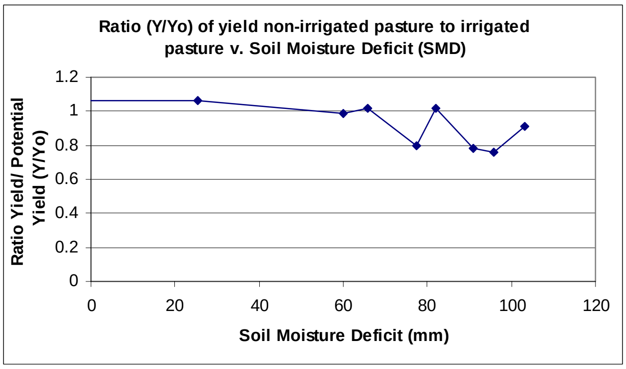

Figure 4. Ratio Yield (non-I pasture) / Potential Yield (I pasture) v. Soil Moisture Deficit.

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Ideally an approximately linear decrease of yield beyond the CD should be found (e.g. Wilson, 1987). Figure 4 shows that the line from the CD (66 mm) onwards is not linearly related to SMD, up to the maximum of 103 mm (which occurred at the end of week 4). This apparent inconsistency can be explained by the fact that the results in Figure 4 represent *weekly* yields of pasture. By contrast experiments showing a linear relationship (Wilson, 1987) are based on cumulative, *whole season* yields, which would produce a smoother relationship.

Observation point 5 (SMD 82mm, Y/Yo = 1.02) quite strongly deviates from the expected descending line. This point represents 'Harvest 1', taken 1 week after the initial cut. The pasture had been uncut for several weeks prior to the initial cut, i.e. had experienced a rest period. It is known that in previously rested pasture, the cutting of white clover causes a stimulated growth (Grant and Barthram, 1991). Thus point 5 in Figure 4 is consistent with this 'rebound' effect in clover growth.

Thermal time

Cumulative DM was plotted against thermal time (°C-days), and the base temperature T_b was adjusted to optimise the fit of a linear regression (Figure 5). The resultant T_b = 3°C is consistent with Moot et al. (2000), who found T_b ranging from 0 to 4°C across several temperate grass and legume species.

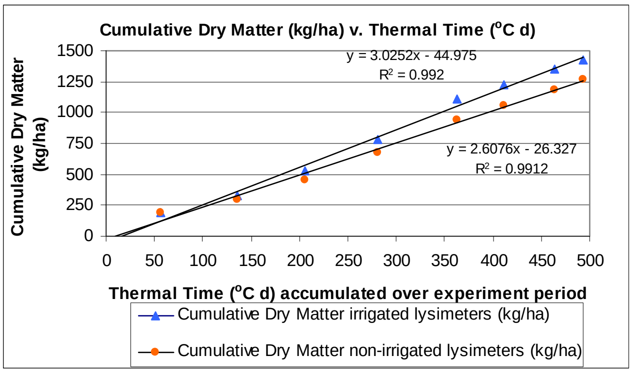

Figure 5. Cumulative Dry Matter related to Thermal Time.

Water use efficiency (WUE)

Figure 6 shows cumulative DM versus cumulative potential evapotranspiration E_p. For the irrigated pasture (which was unstressed and therefore had actual evapotranspiration E equal to E_p), Fig. 6 represents the efficiency with which it 'converts' water use into dry matter. The average WUE for irrigated pasture was 12.9 kg/ha per mm. For comparison, Martin et al. (2006) state that "a WUE of 19 kgDM/ha per mm of Penman PET … is a reasonable benchmark for pasture production on efficiently irrigated dairy farms in Canterbury", with values of about 12.0 kg DM/ha per mm being typical of average farms. Our WUE is lower than this benchmark because a) the lysimeters received no fertiliser treatment during the experiment, and b) the experiment ran in the cooler autumn season.

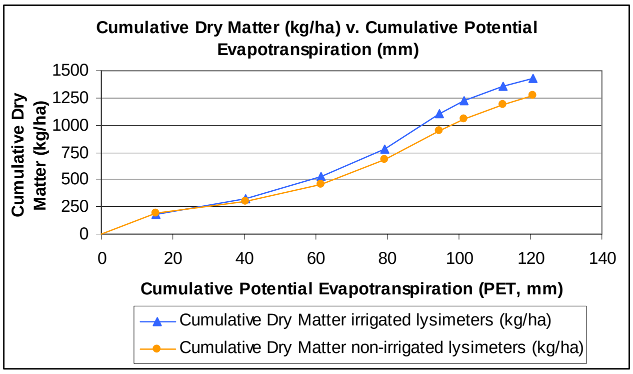

Figure 6. Cumulative dry matter production v. cumulative potential evapotranspiration (E_p).

While Figure 6 shows the eight-week trend of DM gain versus E_p, Figure 7 shows weekly WUE values, obtained by dividing weekly DM gain by weekly E_p. Note that for the non-I pasture, Figure 7 shows 'apparent' WUE values, because non-I lysimeters were under water stress (with E < E_p) for weeks 1 to 5. For the last three weeks (the end of autumn), SMD < CD for the non-I lysimeters, so water stress is removed. Then WUE values of both I and non-I lysimeters decrease and become closely similar.

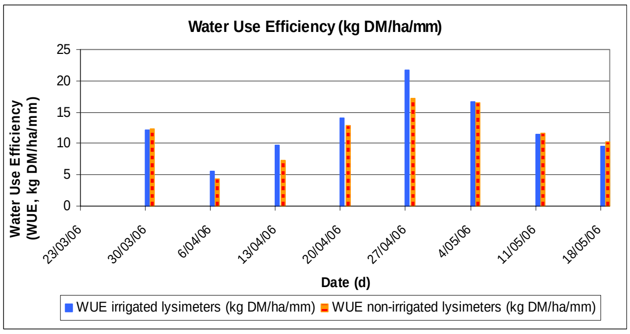

Figure 7. Weekly Water Use Efficiency values of irrigated and non-irrigated autumn pasture.

Note: For the non-irrigated lysimeters, SMD exceeded the critical deficit (CD) in weeks 1 to 5, while for the last three weeks rainfall reduced the SMD below the CD.

Solar energy capture efficiency

Additional data for solar radiation enabled us to determine the efficiency of photosynthesis in terms of the capture and storage of solar energy. Averaged over the whole eight-week period, the irrigated pasture produced 3.0 kg DM per MJ of solar radiation received. Since the *Gross Energy* (GE) content of most pasture feeds is 18 to 19 MJ/kgDM, this implies that the pasture was operating at a 'radiation capture' efficiency of c. 0.56%, in terms of the harvestable (grazeable) component of pasture. However for ruminant livestock the *Metabolisable Energy* (ME) content is only c. two thirds of GE, giving a metabolisable energy efficiency of c. 0.32%.

Conclusions

Some of our key findings are as follows.

- Critical Deficit. Late season pasture irrigation, as commonly practised on Canterbury dairy farms, is effective as long as it serves to keep the Soil Moisture Deficit below the Critical Deficit, in this case below 66 mm. Under the conditions of the 2005–06 season, irrigation contributed to increased pasture yields until the first week of May. By identifying the transition point where irrigation no longer contributes to pasture production, over-irrigation on the edge of the season can be avoided.
- Water Use Efficiency. Our WUE value for irrigated pasture of 12.9 kg DM/ha per mm compares well with values reported by Martin et al. (2006).
- Base temperature. Plotting DM production versus thermal time indicates a base temperature for autumn growth of ryegrass-clover pasture of c. 3°C.
- Solar Energy capture efficiency. For the harvestable component of irrigated autumn pasture, *gross* energy (GE) capture efficiency was 0.56%, while *metabolisable* energy (ME) efficiency was c. 0.32%.
- Economic aspects. A desirable next step is to assess the *economic* effectiveness of irrigation, in terms of a "dollars in/dollars out" (DIDO) analysis. This would require data for a) the costs of applying irrigation water ($ per ha per mm), and b) the economic value of pasture DM ($ per kg DM). However these quantities are highly variable and difficult to determine, and require a separate study.

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References

Grant SA and Barthram GT 1991. The effects of contrasting cutting regimes on the components of clover and grass growth in microswards. Grass and Forage Science, 46: 1-13.

Martin RJ, Thomas SM, Stevens DR, Zyskowski RF, Moot DJ and Fraser TJ 2006. Improving water use efficiency on irrigated dairy farms in Canterbury. NZ Grasslands Association Conference, 2006.

Moot DJ, Scott WR, Roy AM, Nicholls AC 2000. Base temperature and thermal time requirements for germination and emergence of temperate pasture species. NZ J. Agric. Research, 43:15-25.

Wilson DR 1987. New Approaches to Understanding the Growth and Yield of Pea Crops. In 'Peas: Management for Quality'. Agronomy Society of NZ, Special Publication No. 6.

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Ashby's Law of Requisite Variety

A control system always has to be more complex than the system it is controlling.

This is one of nature's (and policy's) most inconvenient laws, being responsible for many, if not all human (and policy) disasters.

WR Ashby 1956
An Introduction to Cybernetics
Part 2: Variety
Methuen, London

Gall's 1st Axiom

Systems in general work poorly, or not at all.

John Gall, 1978
Systemantics

Gall's 15th Axiom

A complex system that works is invariably found to have evolved from a simple system that worked.

Loc. Cit.

Gall's 16th Axiom

A complex system designed from scratch never works, and cannot be patched up to make it work.

Ditto

Gall's 28th Axiom

When a fail-safe system fails, it fails by failing to fail safe.

Ditto

WHO PRODUCES **WISPAS?**

WISPAS is produced by a team of five, namely the Editor and three Regional Correspondents who cover news and activities from their respective research communities and nearby institutions, plus Cathy Isles who prepares the copy and mails WISPAS out. If you have any material that you think may be suitable for the next issue of WISPAS please contact your nearest Regional Correspondent or the Editor. WISPAS is published by HortResearch.

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Best Enemies

'Once you've decided, don't delay. The best is the enemy of the good … a good plan violently executed now is better than a perfect plan next week.'

General George S. Patton

Accelerating Natural Capital?

The ability to exceed temporarily the carrying capacity of the earth can help people live longer, but put our natural capital in decline. Stated in another way, the ability to accelerate a car that is low on gasoline does not prove that the tank is full.

Paul Hawken, Amory Lovins and L. Hunter Lovins. 1999
Natural Capitalism: Creating the Next Industrial Revolution
Little, Brown & Co. NY